Instrumentation for Geophysics and Astrophysics
No. 26

Research Report

Evolution of the ANNA-1 Satellite Optical Beacon

T. WIRTANEN

TERRESTRIAL SCIENCES LABORATORY PROJECT 7600

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES, OFFICE OF AEROSPACE RESEARCH, UNITED STATES AIR FORCE, L.G. HANSCOM FIELD, MASS.

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Abstract

ANNA-1, the first geodetic satellite, carries the first optical beacon system designed for geodetic space experimentation. The ancestry of the flash tubes used in this system is an interesting example of the evolution of a component before it actually flies as part of a scientific satellite's payload.

During the gestation period of the ANNA-1 satellite, the optical beacon underwent several major changes which were directed toward increasing the utility and reliability of the beacon, as well as its compatibility with other instruments in the ANNA-1 Satellite.

A prerequisite for satellite experimentation is the ability to make major physical changes to the experimental package without altering the experiment's potential.

Evolution of the Design of the Anna-I Satellite Optical Beacon

Satellite geodesists presently describe the ANNA-1 Optical Beacon as the 'Model T' of the satellite-borne lights. While it is the first of such lights to be placed in orbit, it does not resemble the original conception of a satellite optical beacon. A study of this light's evolution will elucidate the complexities of instrument-design changes common in satellite exploration.

On approximately 22 March 1960, Air Force and Navy representatives met to discuss the feasibility of placing a stroboscopic light on a Transit navigation satellite in order to make photographic observations of the flashes against a stellar background. These observations would be used to establish space positions of the flash images which in turn would be used in a program of three dimensional triangulation to establish the geodetic positions of the various observing stations. In addition, they would provide a means for calibrating the Navy's doppler range-rate system.

As a result, on 17 June 1960, Air Force Cambridge Research Laboratories entered into a contract with Edgerton, Germeshausen and Grier, Inc., Boston, for the design and, ultimately, the fabrication of a stroboscopic light unit for use in satellite geodesy.

The original specifications given the contractor were:

a) Total weight of unit – 40 pounds
b) One light with 170° conical beam
c) Mounting to be on north pole of satellite relative to its spin axis
d) Total system lifetime – 500 flashes minimum
e) Minimum time between flashes – 20 seconds
f) Each flash sequence would consist of approximately 9 flashes
g) Minimum light output – 6300 beam candle-seconds.

(Received for publication, 15 February 1963)

With these specifications in hand, the contractor proceeded to design and then construct a breadboard model of a flashing light as shown in Figure 1.

Figure 1.

As conceived, the flash unit would receive power into its own battery bank from an external solar-cell source, mounted on the skin of the satellite, through a converter circuit (lower 'doughnut') which charges the capacitors (upper 'doughnut') with 900 volts in approximately 22 seconds. The flash tube is a helix, EG&G Type FX-29, mounted in a 12-inch hemispherical reflector. This unit was tested many times, using a 12-volt automotive-type storage battery as power source.

Approximately two weeks after the contract's inception, the contractor delivered the breadboard mock-up shown in Figure 1. This light was designed to demonstrate that a dependable high-intensity strobe light could be placed in a package reasonably compact enough to be considered for satellite use.

With this breadboard as a starting point, AFCRL met with the contractor to begin the delineation of a working design and specifications for the satellite optical beacon. As a result of this meeting, the specifications for the light unit were changed as follows:

a) Reflector design would be simplified
b) The lamp-reflector assembly would contain two flash tubes to give some measure of redundancy in case of individual tube failure.

Figure 2 depicts the changes in the lamp-reflector assembly. This unit now consists of a low-profile, semi-toroidal reflector in which are mounted two semi-circular flash tubes. When fired in unison, these tubes generate a 170° cone of light, with the integrated intensity in excess of 6300 beam candle-seconds.

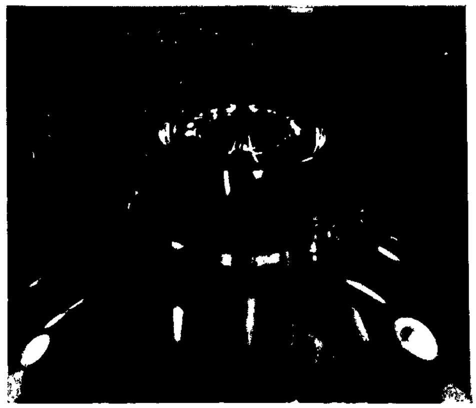

Figure 2.

The entire flashing light package as it looks after these changes is pictured in Figure 3. This view is looking at the north pole of the satellite model. Note that the two 'doughnuts' carrying the internal batteries, converter, capacitor, triggering instrumentation, and now a sequence controller, have been enlarged. Figure 3 also shows the planned mounting of this instrumentation around the structural cylinder comprising the satellite's spin axis.

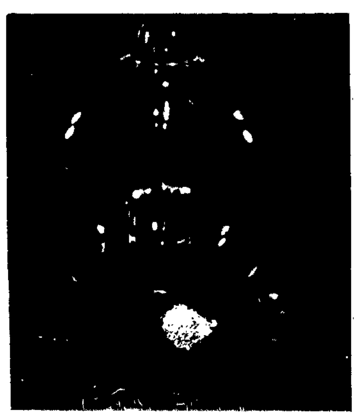

Figure 3.

This satellite unit was designated LS-16 Optical Beacon and for some time it appeared that this beacon system would be the unit to make possible the first

geodetic satellite optical observations. However, within two months, it was decided that this optical beacon would not ride as a 'piggyback' load on a Transit satellite, but instead would be an integral part of the new tri-services geodetic satellite, ANNA. Thus the following requirements were placed on the contractor:

Use the LS-16 Design as a start; design and fabricate an optical beacon which would

a) Have a flash rate of 1 flash per 5+ seconds
b) Place lamp-reflector assemblies at both poles of the satellite
c) Increase total number of flashes to several thousand
d) Provide automatic-sequence controller.

Obviously, these new requirements caused extensive changes to the flashing-light system. Converter circuitry was completely changed with the contractor adopting a modular type of design which gave increased redundancy to the converter package so that the strobe lights could operate satisfactorily, even with one of the six converters not functioning. The heat sink was redesigned. The triggering circuit was redesigned to add selectivity in permitting north or south pole flashes on command. It was deemed necessary that the familiar 'doughnut' packaging of the capacitor, battery, and converter units be replaced by a design which would fit into the satellite's airframe in the equatorial area. Figure 4 illustrates the new configurations of these units, now designated the LS-21 Optical Beacon.

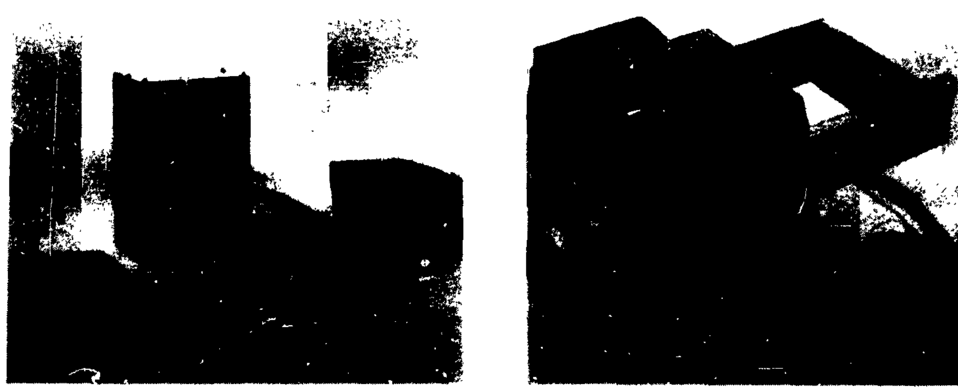

Figure 4.

After the completion of these modifications, it appeared that the LS-21 would be the ANNA-1 Optical Beacon. However, during the tests of the prototype ANNA Satellite, it was found that locations of the light impeded operation of RF instrumentation which is a crucial part of the ANNA instrumentation. As a result, the

lights were moved off the poles of the satellite and placed as near the equatorial solar cell banks as possible. Figures 5, 6, and 7 show the result.

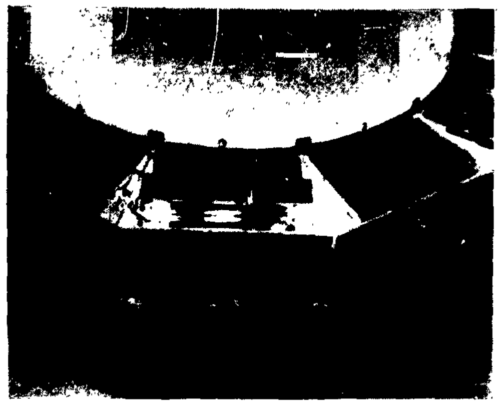

Figure 5.

The lamp-reflector assemblies now consist of a straight EG&G XFX-40 Flash Tube mounted on a flat reflector which in turn is mounted on a flange of the solar cell bank. Note that this straight lamp-reflector assembly replaces one bank of solar cells, whereas the old semicircular shape would have impinged on at least two banks. This unit is canted outward 5° to minimize the effect of the hemispherical bulge of the satellite and to lessen the degrading effect of the light flashes on the adjacent solar cells. The cone angle of the flash is now 150° with an integrated light output of better than 6300 beam candle-seconds.

Figure 6.

Figure 6 depicts the latest configuration of the lamp-reflector assembly, sequence controller, capacitor bank, and converter.

Figure 7.

Figure 7 shows the complete ANNA-1 Satellite. On the equatorial band of solar cells can be seen two flash tube assemblies aimed at the satellite's north pole. Identical units aim at the satellite's south pole. The flash rate is changed to 5 flashes per sequence, 5.6 sec between flashes. Flash duration is 1.2 millisec at 1/3 amplitude points of intensity vs. time waveform. Triggering is designed to flash both tubes simultaneously facing in the same direction.

The converter system has been improved to the extent that it can transform a battery output of 14.5 volts to the 870 volts required for each 5-flash sequence. Each flash tube of a pair is designed to operate at a peak of 8×10^6 cp, permitting successful operation even if one flash tube of each pair should fail. The complete system, excluding batteries, now weighs 52 pounds.

Normal triggering is automatic, since it is received through the satellite memory on command from the central ground station at Applied Physics Laboratory, Johns Hopkins University.

Also, provision has been made for an emergency command-override system. In the event of malfunctions in the automatic command system, the emergency system would transmit a signal to the satellite which would initiate flash sequences on command, independent of the memory system. This by-pass system, also designed and fabricated by Edgerton, Germeshausen, and Grier, Inc., was successfully tested with ANNA-1B on 17 January 1963.

The satellite as shown, is identical to the ANNA -1B Satellite which was successfully placed in orbit on 31 October 1962.

We have traced the design changes mainly for the flash tubes in this instance, touching only briefly on the other components of the system. The same magnitude of changes were required for trigger circuits, heat sink, battery, capacitor banks, sequence controller, and wiring harness. However, this one example will illustrate that the scientist employing satellites as instrumentation vehicles must be ready at all times to alter the physical characteristics of his instrumentation and still maintain the planned experiment potential.

The wisdom of such changes in this specific case can be readily seen in the performance of ANNA-1B as the world's first geodetic satellite.

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2. Navigation
   a. Special navigation systems

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